

Cluster-Cluster Lensing in Abell 2152¹

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We discuss lensing properties of the nearby cluster Abell 2152. Recent work shows that Abell 2152 is actually the projection of two different clusters, one of which is a Hercules supercluster member at $z = 0.043$, while the other is more than 3 times as distant. The cluster centers have a projected separation of only $2'.4$, and our data indicate that the foreground cluster lenses members of the background one. We have an ongoing program to measure the magnification of the fundamental plane in the background cluster. The magnification of this standard rod will provide an estimate of the foreground cluster mass free from the uncertainty of the mass-sheet degeneracy which affects mass estimates based on weak shear.

1. Introduction

The Hercules supercluster is a close grouping of three rich Abell clusters at a redshift $z \approx 0.04$. While the richness class 2 cluster Abell 2151 (the classical ‘‘Hercules cluster’’) dominates from the standpoint of the number of galaxies, the richness 1 cluster Abell 2152 is nearest to the center of the grouping. The third supercluster member is Abell 2147. All three clusters are projected within a radius of only $\sim 1^\circ$ ($\sim 2 h^{-1}$ Mpc) and have velocity dispersions of 700 to 800 km s^{-1} (Barmby & Huchra 1998).

We have found that the cluster catalogued as Abell 2152 is actually the chance alignment of two galaxy clusters: A2152 proper at $z = 0.043$, and a more massive background cluster at $z = 0.134$ which we designate A2152-B. The centers of these two clusters are separated by just $2'.4$, corresponding to 84 h^{-1} kpc at $z = 0.043$. Our analysis of ground-based imaging and spectroscopic data presented below indicates that the foreground cluster is strongly lensing at least one, and likely two, members of the background cluster.

2. The A2152/A2152-B Lensing System

The magnitude $m_R = 18.6$ object labeled ‘A’ in Figure 1 is projected $25''$ north of the A2152 cD galaxy but lies in the background at redshift $z = 0.142$ (Blakeslee et al. 2001). The data were obtained at Keck Observatory using the LRIS (Oke et al. 1995). The curved shape, redshift, and orientation of the object all suggest gravitational lensing. Such instances of low- z cluster lensing in principle allow for higher resolution studies of the core mass profile (e.g., Campusano et al. 1998; Blakeslee & Metzger 1999). However, our detailed modeling of this $z = 0.043$ lensing system required the dominant potential well to be centered on the A2152 cD, rather than on the peak of the X-ray emission, which is positioned $2'.1$ to the east (Jones & Forman 1999). Because of this, we suggested that there was a massive background cluster surrounding a pair of bright $z = 0.13$ early-type galaxies, one of which is located just $20''$ from the reported X-ray center.

Recent ground-based B -band data confirm the existence of a rich background cluster, which we call A2152-B. The ‘‘new’’ cluster shows a well-defined early-type galaxy locus in the color-magnitude diagram of Figure 2. The colors are consistent with the $z = 0.134$ redshift of A2152-B cD galaxy pair. This supports our strong lensing analysis of object ‘A’: the A2152 potential is indeed centered on its cD, but the X-ray center is offset because of background cluster emission. Lensed galaxy ‘A’ itself may well be a high-velocity member of A2152-B. Another possibly strongly lensed *radial* feature (‘R’ in Figure 1) just $11''$ from the A2152 cD may also be in A2152-B, although its $z = 0.13$ redshift is based on a single line, and therefore unconfirmed.

¹ *The Dark Universe: Matter, Energy, and Gravity*, STScI Symposium, 2–5 April 2001, M. Livio, ed.

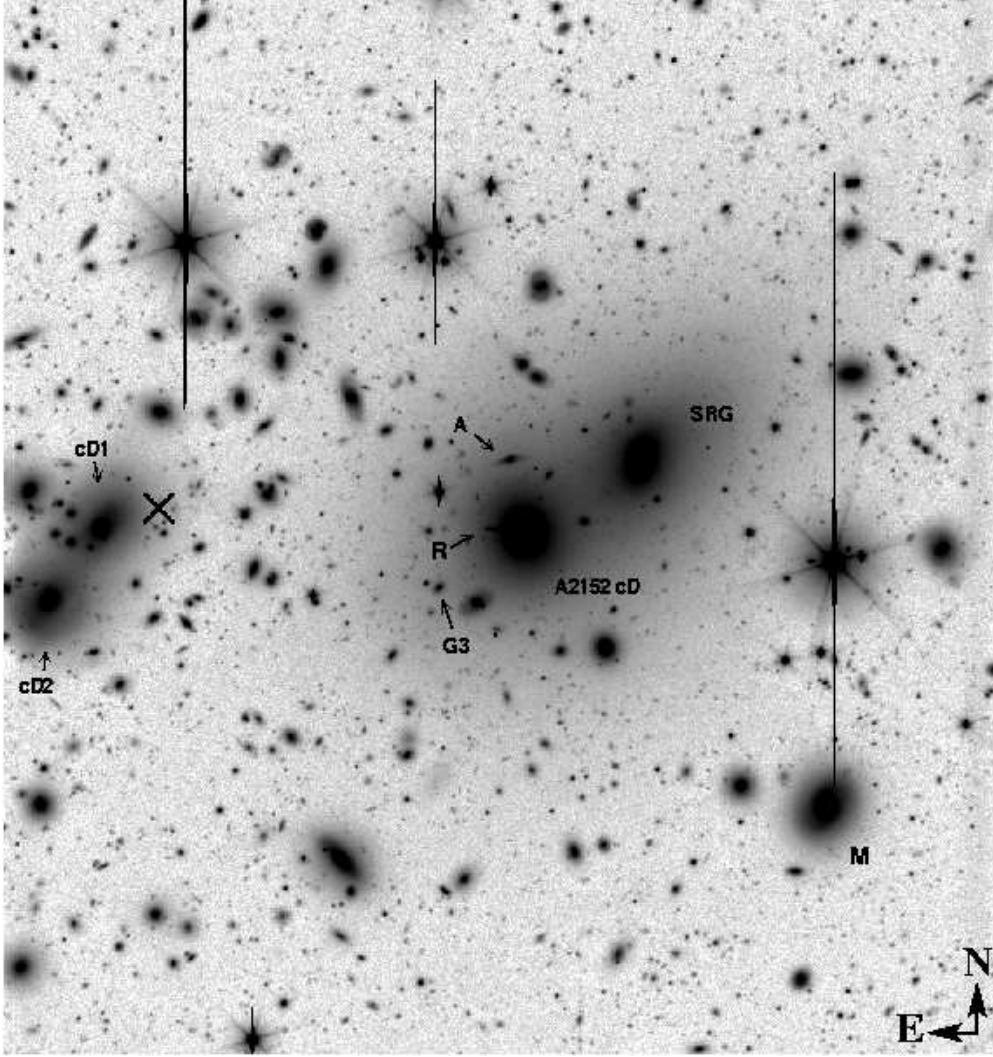


FIGURE 1. A $5/6 \times 6/0$ Keck/LRIS R -band image of A2152/A2152-B. The bright galaxy at center is the $z=0.043$ **A2152 cD**; the second-ranked A2152 galaxy (**SRG**) is $47''$ to the northwest. The two galaxies labeled **cD1** and **cD2** are in the background A2152-B cluster at $z=0.134$. The $z=0.142$ lensed arclet (**A**) appears in the halo of the foreground A2152 cD. A radially oriented object (**R**) with an unconfirmed redshift of 0.13 may also be strongly lensed. Another confirmed early-type member (**G3**) of the A2152-B cluster happened to fall in the slit during long-slit observations of the A2152 cD. A large spiral galaxy in the field with a measured redshift (labeled **M**) is a member of A2152. The position of the X-ray center in this field is shown as a large “X” near the background cD pair. Our $(B-R)$ color data reveal that *most* of the smaller galaxies projected between the A2152 and A2152-B cD’s are A2152-B cluster members.

The A2152/A2152-B system appears to be the first known instance of cluster-cluster lensing. In addition, our images reveal a faint blue arc near one of the pair of *background* cD galaxies, the one labeled “cD 1” in Figure 1. The arc candidate is indicated in Figure 3. If this is a yet more distant source being lensed by the background cluster, then this would make A2152-B a *lensed lens*. Additional arc candidates can be found near the background cD pair but cannot be verified with our current ground-based data.

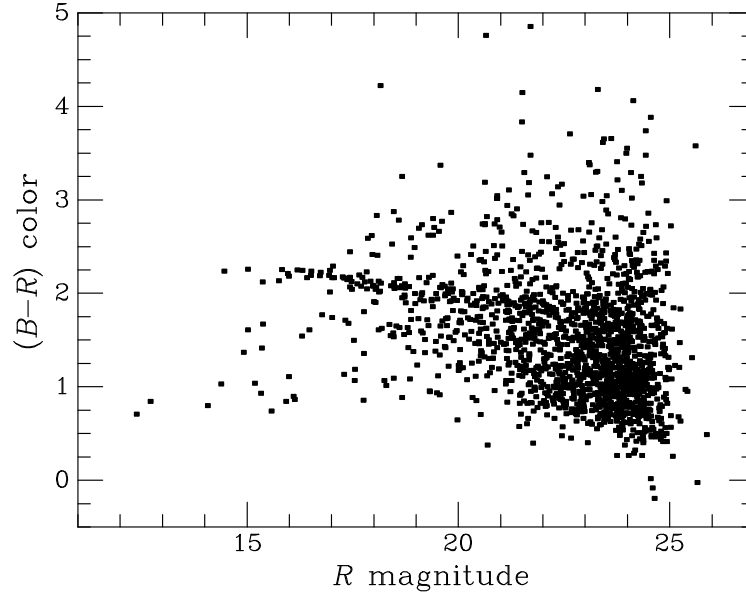


FIGURE 2. The $(B-R)$ color-magnitude diagram for the A2152 field. The early-type galaxy population in the newly identified $z = 0.13$ cluster A2152-B stands out as a roughly horizontal locus at $B-R \approx 2.1$. The foreground $z = 0.043$ cluster locus is harder to identify because of the lower surface density, but is shifted blueward by about 0.4 mag.

A2152-Background cluster core

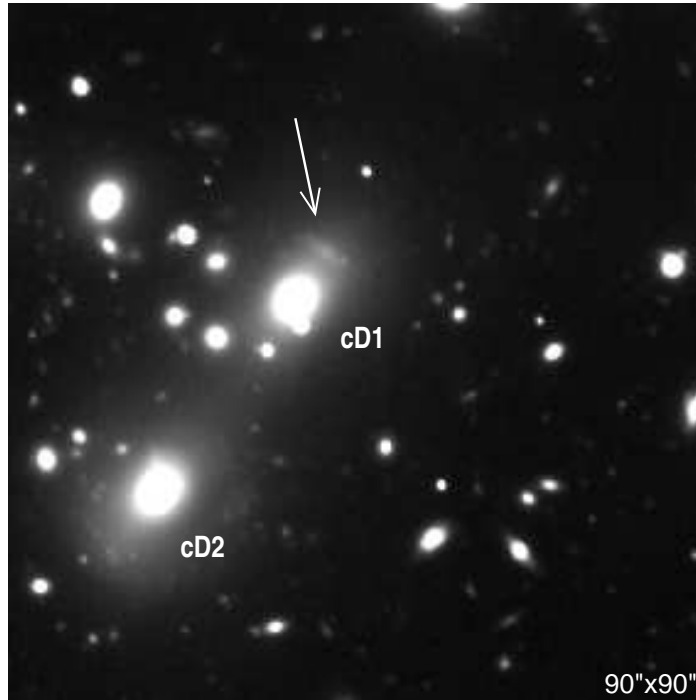


FIGURE 3. A blow-up of the B -band Keck/LRIS image near the cD galaxy pair in the $z = 0.134$ cluster A2152-B. The possible arc in the halo of cD1 is indicated by the arrow. If this can be confirmed as a lensed feature, then this would make A2152-B a lensed cluster lens.

3. A Unique Opportunity

Because gravitational lensing measures only the total projected mass along a line of sight, cluster masses will be overestimated *whenever* there are superposed galaxy groups, sheets, or filaments. This is a particularly severe problem for optically selected clusters, such as Abell clusters. Projection of multiple mass components now appears to explain some of the discrepancies between lensing and X-ray/dynamical masses in several intermediate redshift clusters, including CL0024+1654 (Soucail et al. 2000; Czoske et al. 2001) and RX J0848+4456 (Holden et al. 2001). Abell 2152 offers a unique opportunity to study and disentangle a complex, overlapping cluster mass system at close range.

One benefit of cluster-cluster lensing is the large population of background galaxies at a known redshift. Knowing the redshift of the source population removes a significant contribution to the uncertainty in weak lensing reconstructions of the mass profile. Of course, the addition of weak lensing information for yet more distant sources by both clusters then helps in constraining the background cluster mass profile as well.

Even more exciting is the opportunity to measure the fundamental plane in a lensed cluster. Because of the lensing, the early-type galaxy population in A2152-B should lie “above” the unlensed fundamental plane, i.e., have effective radii and luminosities too large for their velocity dispersions. The magnitude and spatial gradient of the offset will provide a direct measure of the *absolute* mass profile of A2152.

We have recently obtained good quality Keck LRIS multi-slit spectroscopy for about 100 galaxies in the central A2152/A2152-B field. When completed, this will be the first measurement of gravitational magnification of a known standard candle or standard rod. Mass estimates from magnification are unaffected by the notorious “mass-sheet degeneracy” which afflicts all estimates based solely on image shear. The combination of magnification and shear measurements at the same projected radii should greatly enhance our understanding of the mass structure in this complex nearby cluster lensing system.

I thank my collaborators Mark Metzger, Harald Kuntschner, and Pat Côté. I also thank Ian Smail and John Lucey for valuable discussions and help.

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